Aperture Synthesis Images of Dense Molecular Gas in Nearby Galaxies with the Nobeyama Millimeter Array

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Abstract. High resolution images of HCN(1−0) and HCO^+(1−0) emissions from nearby galaxies made with the NMA are presented.

1. Dense Molecular Gas in Galaxies

In order to study the distribution of dense molecular gas and its relation to the central activities (starburst and AGN) in galaxies, we have conducted an imaging survey of HCN(1−0) and HCO^+(1−0) emissions from nearby spiral galaxies with the Nobeyama Millimeter Array (NMA) (Kohno et al. 1996, 1998, 1999a, 1999b, 1999c; Shibatsuka et al. 1999). Figure 1 shows preliminary images of HCN and HCO^+ in galaxies. In starburst galaxies, we find there is good spatial coincidence between dense molecular gas and star-forming regions. The ratios of HCN to CO integrated intensities on the brightness temperature scale, $R_{\rm HCN/CO}$, are as high as 0.1 to 0.2 in the starburst regions, and quickly decrease outside of these regions. In contrast, we find a remarkable decrease of the HCN emission in the post-starburst nuclei, despite the strong CO concentrations there. The $R_{\rm HCN/CO}$ values in the central a few 100 pc regions of these quiescent galaxies are very low, 0.02 to 0.04. A rough correlation between $R_{\rm HCN/CO}$ and Hα/CO ratios, which is an indicator of star-formation efficiency, is found at a few 100 pc scale. The fraction of *dense* molecular gas in the *total* molecular gas, measured from $R_{\rm HCN/CO}$, may be an important parameter that controls star formation. In some Seyfert galaxies we find extremely high $R_{\rm HCN/CO}$ exceeding 0.3. These very high ratios are never observed even in strong starburst regions, implying a physical link between extremely high $R_{\rm HCN/CO}$ and Seyfert activity.

References

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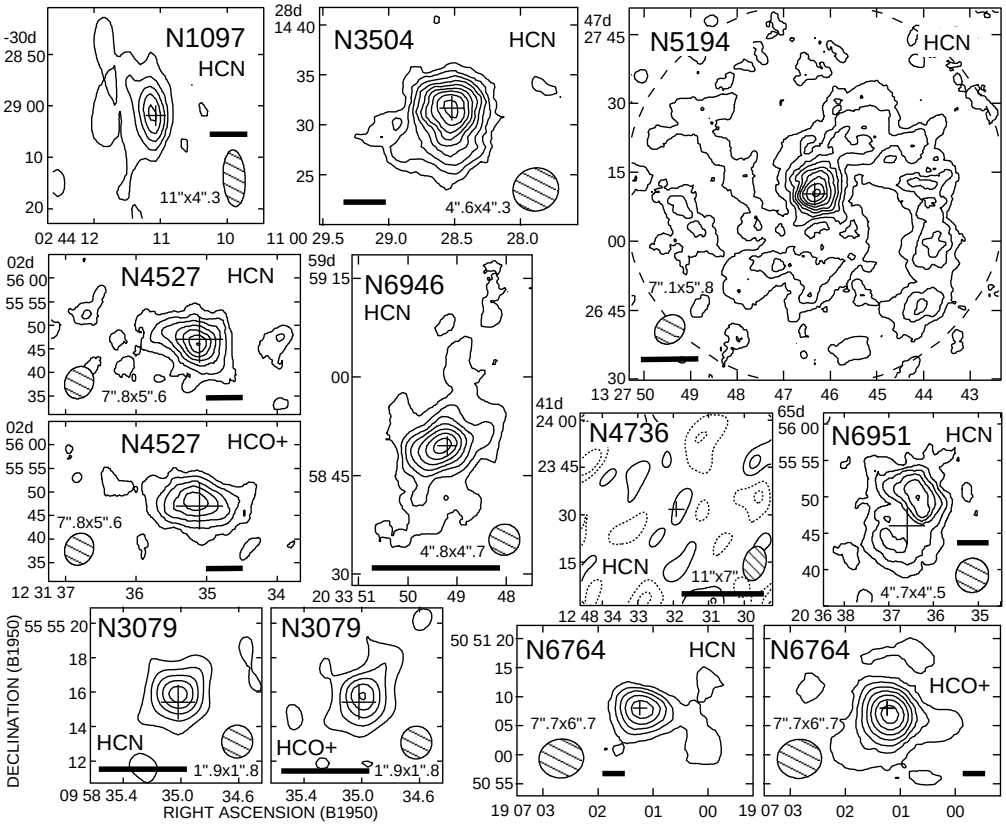

Figure 1. High resolution HCN and HCO^+ images of nearby spiral galaxies. HCO^+ images were obtained simultaneously with the Ultra Wide-Band Correlator of the NMA (1024 MHz band-width). The thick horizontal line in each image corresponds to 500 pc. The cross marks the position of a 6 cm radio continuum peak. The contour interval is 2 σ for NGC 3079, NGC 3504, NGC 6764, and NGC 6946, and 1.5 σ for NGC 1097, NGC 4527, NGC 5194, and NGC 6951. Contour levels are -3, -1.5, 1.5, and 3 σ for NGC 4736. Noise levels are 1.7, 1.5, 0.46, 0.71, 0.91, 0.44, 0.36, 0.83, and 0.58 Jy beam^{-1} km s^{-1} for NGC 1097, NGC 3079, NGC 3504, NGC 4527, NGC 4736, NGC 5194, NGC 6764, NGC 6946, and NGC 6951, respectively. A *nuclear* starburst is hosted by NGC 3079, NGC 3504, NGC 4527, NGC 6764, and NGC 6946, whereas a circumnuclear star-forming *ring* is observed in NGC 6951. Good spatial coincidence between HCN and Hα (and radio continuum) emission can be seen in these star-forming galaxies (Kohno et al. 1999a). Note that there is a remarkable decrease of dense gas in the post-starburst galaxy NGC 4736; the current massive star formation is suppressed in the central $r \sim 10''$ region, even though there is a CO peak. The resultant $R_{\rm HCN/CO}$ is very small, less than 0.044 (2 σ upper limit). The sample contains one type-1 Seyfert (NGC 1097) and three type-2 Seyferts (NGC 3079, NGC 5194, and NGC 6951). A cohabitation of AGN and starburst has been reported to have taken place in NGC 1097, NGC 3079, and NGC 6951.

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